

TOWARDS ECONOMIC SUSTAINABILITY THROUGH ADAPTABLE BUILDINGS

Anupa MANEWA¹
Christine PASQUIRE Dr²
Alistair GIBB Prof³ Robert SCHMIDT⁴

¹PhD Scholar, Department of Civil and Building Engineering, Loughborough University, Loughborough, UK, R.M.A.S.Manewa@lboro.ac.uk

²Senior Lecturer, Department of Civil and Building Engineering, Loughborough University, Loughborough, UK, C.L.Pasquire@lboro.ac.uk

³Professor, Department of Civil and Building Engineering, Loughborough University, Loughborough, UK, A.G.Gibb@lboro.ac.uk

⁴Research Associate, Department of Civil and Building Engineering, Loughborough University, Loughborough, UK, R.Schmidt-III@lboro.ac.uk

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Abstract

The existing building stock in most countries does not meet the parameters of economic, social and environmental sustainability. Physical, functional, technological, economical, social and legal obsolescence are the principal factors driving the decommissioning, refurbishment, alteration and/or adaptation of a building. In the UK the Government promotes optimum use of the existing building stock through mixed use in urban centers and encourages conversion of redundant office and retail space into leisure, service and/or residential uses rather than demolition and renewal. There is therefore a growing need to design new buildings that are adaptable and flexible over their life span whilst at the same time improving user satisfaction. A constraint to the implementation of a policy of life span adaptability is the difficulty of understanding the economic considerations over long time scales. This paper investigates the issues surrounding the economics of the life span of adaptable buildings, and establishes a conceptual framework for their economic sustainability.

The investigation is based on a case study of how the uses and function of the built environment and its supporting infrastructure have changed over a period of 100 years undertaken within a semi-rural Borough in England, UK. This case study includes a trend analysis identifying the life spans (of buildings), the evolving planning policies and associated social and cultural issues. A conceptual framework is developed and the economic impacts of the changes are evaluated through Whole Life Analysis. The validity and reliability of proposed framework is yet to be tested.

1. Introduction

A revolution in agricultural and industrial sectors in the 18th century wrought a remarkable change in social, cultural and economical life styles in the UK. As a result, major changes could be seen in patterns of land ownership and land use during the last century (Butlin, 1994). Today, the UK Government tends to promote optimum use of the existing building stock through mixed use in urban centers and encourages conversion of redundant office and retail space into leisure, service and/or residential uses rather than renewal. Pitts (2004) further suggests the promotion of mixed use developments in the UK will reduce the need for travel to work by private vehicles, make local facilities more viable and encourage the community spirit helping to achieve sustainability goals. Therefore it is important to analyse ways of utilising the existing building stock as mixed or sole use developments, because building functions have limited life, they are expensive to build, and the cost of replacement is high and clearly unnecessary where they are physically robust and adaptable. This is encouraging greater innovation in the design of new buildings to allow for change of use throughout the structure's lifetime. Recently there has been a growing need for adaptable building developments in the UK.

Previous research has concentrated on innovations in information technology, new working practices, tightening of the environmental agenda (Kincard, 2000), and rapid change in private and public organisations, changing user needs and effects of obsolescence (Arge, 2005) as factors which influence the adaptability of buildings. Most of the conventional buildings are one-off and not designed for mass customisation. But adaptable buildings might focus on bespoke solutions which, wherever possible, are flexible to varying customer needs.

The purpose of this paper is to identify how the functional uses of buildings change over time using a Morphological Analysis within a semi rural Borough in UK over a 100 year time span. The study further investigates the factors behind those transformations and proposes how buildings could adapt for those changes without demolishing the entire structure. Moreover a conceptual framework is developed to explore the economic impacts of adaptable buildings.

2. Research Methodology

The town of Loughborough was used to represent the changes of buildings over the last century. It is a typical small rural town in the heart of the United Kingdom. The available historic maps and documents were collected from Leicester Record Office, and Loughborough public library. An extensive Morphological Analysis was carried out within the area to study how building functions have changed and to establish the factors behind those changes. A previous research study using morphological analysis was undertaken by Ariga (2005) on adaptable physical settings and flexible mixtures for livable urban communities in the city of San Francisco. It focused on functional clusters and their adaptability with the changing conditions. Similarly, morphological analysis is used to identify the pattern of change in building functions in a selected building cluster in Loughborough during the last century. A morphological analysis is a general method for non quantified modeling, consequently, it is considered as a classification system made up of categories that divide some aspects of the world into parts (Ariga, 2005). In this sense, the same method is used by the research described in this paper to investigate the space use pattern in buildings (either mixed or sole use) and their surrounding structures.

The main types of building were identified as residential, commercial, industrial, social and leisure categories. Residential included detached, semi-detached, houses and apartment blocks. Commercial comprised offices, banks, public houses, hotels and retail categories. Industrial included buildings for manufacturing and warehouses. Social covered schools, churches, clubs, hospitals and buildings which were built for community wellbeing. Leisure included parks and other recreational facilities. Historic maps to a scale of 1" = 88ft and for the years 1886, 1901, 1921, 1968, 1970, 1974, 1981, 1989, were used to study the pattern of functional transformations of buildings over the years. Among those maps, critical differentiations of functional uses were identified from 1886, 1921, 1970 and 1989. Other historic documents were also accessed to identify the factors behind the transitions. A semi structured interview was conducted with one of the development and control officers in the Local Authority (Charnwood Borough Council) to obtain the platform data for the study and to identify the economic impacts derived from the changes observed. The interview supported the selection of the specific case study area in the town. This comprised the area bounded by Market Place, High Street, Woodgate and South Street. The main reason for selecting this area was its' frequent changes in space and its' representation of all the functional units better than the other possible clusters. The selected cluster is located at the commercial hub of the town of Loughborough.

Moreover, direct observations of the existing building stock within the area were carried out to identify their most recent uses. This observation revealed which buildings had been replaced in recent times as the construction technology was clearly less than 60 years old and helped to estimate the percentage of alterations in buildings and their functions.










3. Data Collection and Analysis

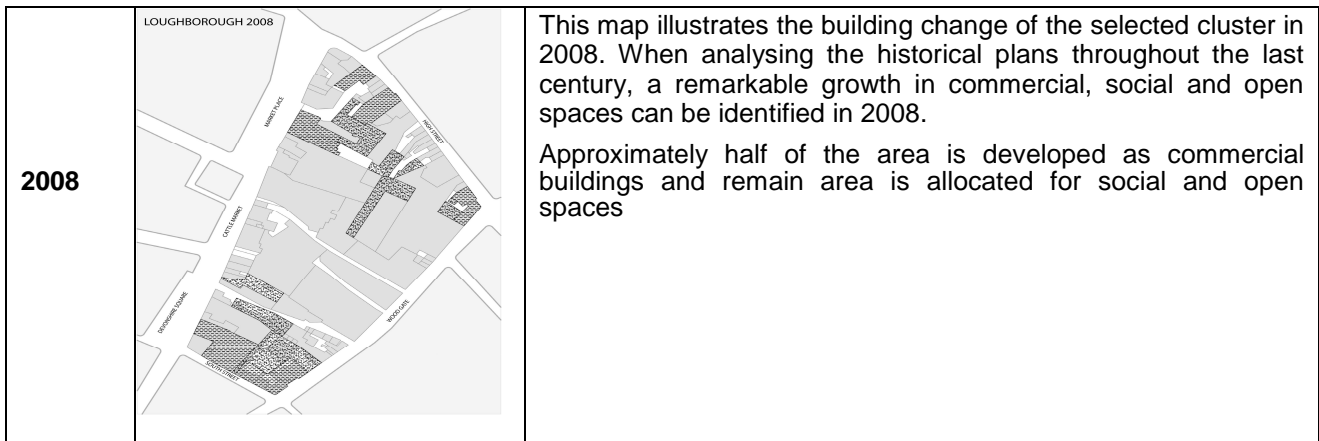
The industrial revolution in the 19th century caused rapid developments in the town based on hosiery, other textile productions, and various manufacturing and engineering industries. It appears that the charter of incorporation in 1888 was largely the result of the industrial prosperity of Loughborough (Deakin,1974). Although relatively undamaged physically by the First and Second World Wars in the first half of the 20th century, there was a disruption to the growth pattern of the town during these periods whilst the growth of public policies in the late 20th century has favoured changes in space : use patterns.

3.1 Case Study

The case study was carried out to identify the pattern of building change in Loughborough. A cluster area was selected through a preliminary survey which identified the maximum number of multi functional (residential, commercial, industrial, social, leisure) units within a single area. The cluster area referred to in this paper is the surrounded by roads and shows remarkable changes in both the functional and spatial transitions.

Table 1 : Pattern of Building Transitions

Year	Cluster Maps	Spatial Transition
1886		<p>This is the base line map used for the study. The area is bounded by High Street to the north, Woodgate to the East, South Street to the south and Market Place to the West. Residential buildings were placed along Woodgate and South Streets as semi detached houses. Most of the detached houses were scattered over the middle part of the cluster. The town hall and police court can be identified under the Social category. There were commercial buildings, such as banks, hotels, small shops and a few public houses with Industrial buildings surrounded by the residential units at the centre.</p> <p>The variation of building type was highlighted on the location maps by assigning the following shades to each functional unit.</p> <p><u>Change of Use</u></p> <ul style="list-style-type: none">  Social  Commercial  Industrial  Residential  Leisure/ Open space
1921		<p>Spatial extensions in social (Town hall) and commercial buildings (bank, hotels) could be easily identified through the 1921 map. A new picture theatre and National Westminster bank were added to the social and commercial building networks respectively. But no remarkable alteration to the remaining building stock could be seen in 1921.</p> <p>Impact of the First World War (1914 – 1918) was not noticeable.</p>
1970		<p>By 1970 many changes could be easily identified. Since 1921, new building and extension had taken place in all the functional categories.</p> <p>Specific new construction (Corporation Yard, Woolworths, Police Station) and conversions of existing buildings (Part of an existing police station becomes a Magistrate Court, Midland Horticultural Works become Clemerson's Storage), could be highlighted during this period. More spaces were also allocated for commercial, social and industrial buildings. Some of the Victorian residential buildings were demolished and some were converted to other functions. The cluster started to commercialise after the Second World War adding growing employment opportunities for the people at Loughborough. As a result, the town economically stabilised in 1970.</p>
1989		<p>It can be seen that more spaces were added to the existing commercial stock since 1970. All the residential buildings were replaced by the other functional units.</p> <p>A larger area has been allocated as open space in 1989 than in 1970. There is no evidence of significant development in the existing stock or new construction.</p>



3.2 Economic Growth

The morphological analysis illustrates a demand for various buildings in different time periods. It is proposed that analysing the economic impacts from these changes will enable a framework to be developed that assists with the projection of potential future functional requirements of the built environment. To this end four economic indicators were identified (see 3.2.1 to 3.2.4) and analysed by considering all the clusters in general at Loughborough and their impacts on building transition.

3.2.1 Growth in the Industrial/Manufacturing Sectors

A growing trend in the industrial sector a century ago demanded a change in building type to fit the new purpose. The historical maps indicate that in the 19th and early 20th centuries many of the buildings were utilised for manufacturing lace, bells, cranes and electrical products along with heavy industries such as iron foundries, corn mills, warehousing and goods handling on canal wharves. It seems that the Brush Engineering Company Ltd was Loughborough's largest manufacturing group in that era. Other employment opportunities were offered by John Taylor's bell-foundry in 1839, Ladybird Books Ltd in 1873, and Davy Morris's crane works in 1903 (Wix et al. 1994).

It would appear that these industrial buildings were very large, spacious and well engineered to accommodate the heavy machinery and large work force. By the turn of the 21st century however, it could be seen that most of these industrial buildings had been converted to other functional units such as residential, commercial, social and retail facilities with certain improvements (eg. Towles Mill building). However, designing buildings for adaptation is one of the present day's solutions for a knowledge based, profit orientated economy with rapidly changing product ranges. Reusability created by adaptability of buildings will significantly contribute to economic sustainability.

3.2.2 Growth Rate of Population

It is obvious that the growth of population is one of the significant economic factors that drives the need for extra housing. So the changes in population growth in Loughborough compared to the English average during the last century has been calculated (Figure 1) in order to gauge it's influence on the local built environment. The formula used to calculate the growth rate is;

$$\text{Growth Rate} = \left\{ \left(\frac{\text{Population in ending year}}{\text{Population in beginning year}} \right)^{\frac{1}{\text{Number of years}}} - 1 \right\} \%$$

Source : <http://www.measuringworth.com/growth/#>

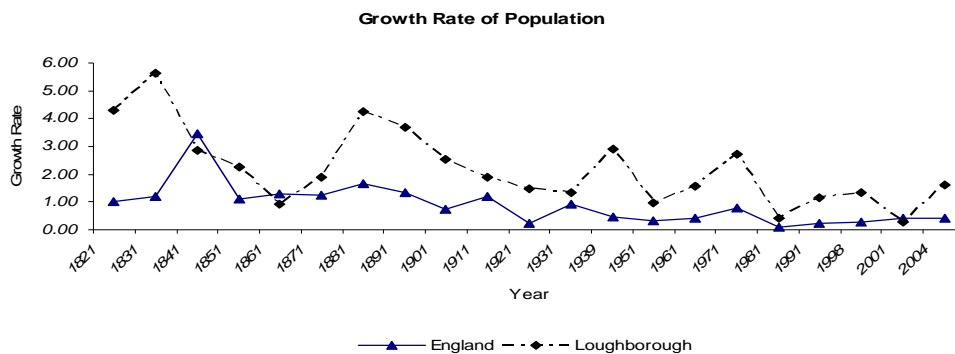


Figure 1: Growth Rate of Population

Sources : The office for national statistics, www.statistics.gov.uk/statbase/product.asp?vink=601&More=N Atlas of the Borough of Charnwood, 1990 pp 51 and www.leics.gov.uk/,

The graph in Figure 1 shows the population growth of Loughborough to be largely higher than national growth rate only dropping below the national rate in 1845 and 1865. The local growth rate trend has followed the national one but the difference between the two growth rates has noticeably diminished over time. The local rate is more erratic although this is likely to be due to the increased sensitivity of the smaller numbers involved in its calculation. More recent digression in the trends occur in 1946/1956 caused by WW2 and 1970/1975 caused by the establishment of the University with its associated influx of employees.

The growth of population in Loughborough has been creating many challenges to the built environment and its policy makers. However the expansion of buildings to continue the existing functions, demolition of redundant buildings and functional conversion of most of the buildings in the cluster could be seen in parallel to the population growth with the space allocation for building developments rising. The high frequency of functional conversions rather the structural changes in the existing building stock can be further highlighted.

3.2.3 Growth of Higher and Further Education

Significant development in the higher and further educational sectors in the town occurred in 1966 with the incorporation of the university charter. This placed the new university on one of the largest single site campuses anywhere in the UK and made it the largest employer in the town of Loughborough (Herbert, 1996). The growth rate of the student population during the last two decades is graphed in Figure 2. This growth has demanded additional space for student accommodation and associated commercial and leisure facilities within the selected cluster. Further it has outstrip the availability of existing facilities resulting in significant new build programmes to cater for the community needs and wants.

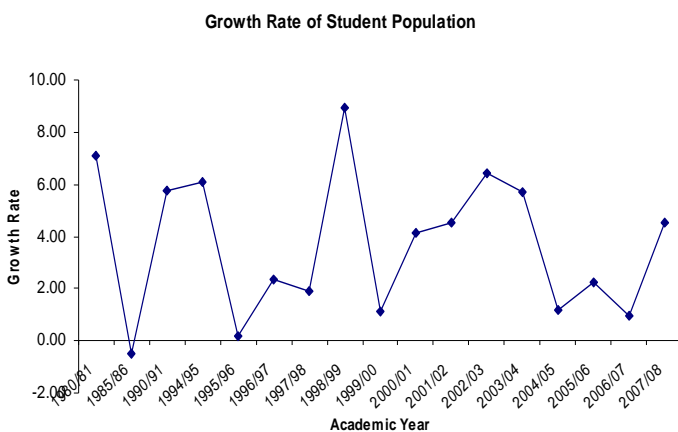


Figure 2 : Growth of Student Population in University of Loughborough

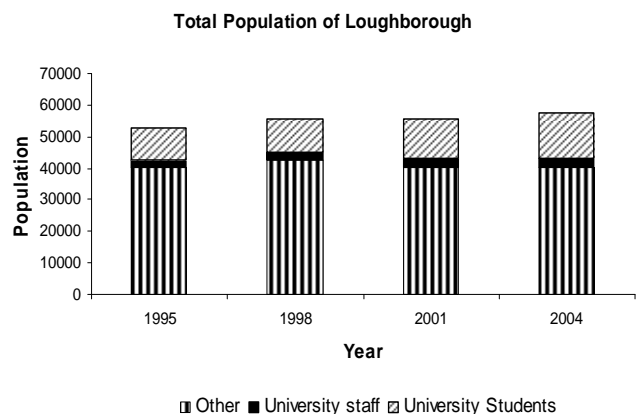


Figure 3 : Population Distribution of Loughborough

Source : Facts and Figures, University of Loughborough, <http://www.lboro.ac.uk/admin/ar/planning/stats/factsfigures/index.htm>

The increase in student numbers' growth rates in different periods (1988-1995, 1996-1997, 1998-1999, 2000-2003, 2005-2006, 2007-to date) is highlighted in Figure 2. Consequently, Figure 3 illustrates the population distribution of Loughborough in the last decade. The university population represented 23.75%, 23.42%, 27.52% and 30.11% of the total population in 1995, 1998, 2001 and 2004 respectively. Approximately, it is around 1/3 of the total population of Loughborough. According to the recent university publications the total staff and student population is 19,156 in mid May 2008 and was 17,334 in 2004. This growth might affect Loughborough's economic growth because of increase purchasing power of the students and staff. However, a lack of published data on student, staff, and other categories in remain years caused not to identify any link between the cluster development. But it appears the continuous growth in university population as well as a growing demand towards commercial buildings with in the cluster.

3.2.4 Planning Policies

Considerable effects from planning policies on building construction can be seen in Loughborough after the formation of Charnwood Borough council in 1974. All buildings are now to be constructed according to the county structure plan (Wix and Keil, 2002). The policies are derived from a two tier activity. The national government policy statement sets the framework for the whole country and local authorities then apply it to work in their regions. Most of the policies are concerned with environmental sustainability.

The policies are biased towards increasing 'Brownfield' development (reuse and redevelopment of previously developed land) and limiting 'Greenfield' development (new construction on previously undeveloped land). Moreover the policies favour an increase in housing to meet the fast expansion of the elderly, single parent and disabled population in the county (Wix and Keil, 2002). In seeming contradiction to this a critical growth and transition in commercial and industrial zones can be identified through historical plans. This has directly affected Loughborough's traffic system, and new plans and regulations were developed to keep the market town away from the residential zones. It can be clearly seen through the above case study that there has been a shifting of residential buildings to locations away from the cluster area and that this part of the town has become a commercial hub for Loughborough.

4. Results and Discussions

Geraedts (2008) states the current building stock is more towards long structural, short functional life and more concerned to fit the sustainable agenda. His evidence further illustrates the existing building stock is no longer meeting the present day user's needs and this leads to an increasing the number of vacant buildings. As a solution for this dilemma he suggests an effective means to incorporate adaptable, recyclable, sustainable, consumer oriented, flexible and open building concepts should be found. It is valid for the selected cluster too. The morphological analysis shows that most of the buildings, around 83% faced functional transitions during their sole structural life span. However the result further illustrates that approximately, 30% of total demolitions were carried out in the cluster during the last century. From this it is obvious there is a need for designing buildings which can change without physical damage to the structure is also a way of optimising sustainable goals by reusing the existing resources.

All the functional mixes could be identified within the cluster during the 1886. However the cluster started to commercialised in 1970. Residential buildings were totally shifted away from the cluster and more commercial and social buildings were accommodated. Policy makers were strived to separate the residential sector from the market segment. As a result some of the existing residential houses were required convert offices, pub houses and some were totally replaced from 1970 map. The growth in local population, increase of spending power, implementation of new planning policies, sustainable concerns, changing user demands and building obsolescence can be identified as the key factors behind those transition.

In the aftermath of the WW2, the sudden growth in all the sectors in Loughborough is highly remarkable. The shifting of houses to discrete residential zones and the mushrooming developments in commercial zones is significant. The improvements in spaces for banking shows the growth in monetary transactions from the earlier periods. As one of a large prospective employers, university plays vital role in this sense. In 1886 only Lloyds bank can be found on the map, in 1921 Westminster bank is added to the commercial network. In 1970 the expansion of both banks can be seen and another branch of Westminster bank is added to the cluster by 2008 there are HSBC, National Westminster and Lloyds bank placed in the cluster. So the growth in banking and some expansion in social structures could be highlighted within the cluster. Those improvements affected the economic booms in Loughborough during the periods.

The industrial diffusion in the cluster is significant when analysing the economic growth in Loughborough. The Midland Horticultural Works had provided more employment opportunities to people surrounding Loughborough in early years. Then this space was used as storage for Clemersons. Even though the function changed from industrial to commercial (retail) the same structure was performing the different functions. Moreover, a continuous growth in social and leisure buildings could be identified within the cluster. Extensions in the Town Hall building to receive a big crowd at once and construction of new police court, renewal and partially conversion of existing police court to magistrate court is notable. The growth in population is one of the leading factors which drives expansions leading in the long term to social improvement, sustainable goals and community wellbeing.

It was derived from the interview and the observations that the economic, social, environmental parameters and obsolescence are the key demanding factors for building space. Either factor can create significant demand for space. However, new buildings which can be adapted to new functional goals have been identified the solution to cater for growing demand. The term 'Adaptable' is a multifaceted concept. It is about managing 'change' in the context of buildings which can occur as a result of either exogenous (external) or endogenous (internal) influences (Douglas, 2006).

The research study undertaken by 'Adaptable Futures' concerns the effective and efficient ways of deliver adaptable solutions to the UK construction. Moreover the team identified flexible, available, changeable, moveable, reusable, refittable, scalable as the higher level strategies of adaptability, which incorporates with specified lower level strategies. This study supports to the main research by identifying building changes, factors behind the change and to develop a framework for measure the economic feasibility of adaptable solutions over the new building.

4.1 Conceptual Framework

Other than the above features the performance criteria, in terms of economic concerns is linked to the conceptual framework illustrated in Figure 4. Through the morphological analysis it was identified the most significant driving factors, which leads for the functional transformation of buildings in the cluster. Around

30% of buildings were demolished and new construction were undertaken as a solution. The main reason was less physical robustness to accommodate new functions and/or failed to continue the existing functions. Hughes et al. (2004) identify that short lifetimes reduce a building's value without reducing costs – simply, because there is no way of economically constructing a building for a short life. It is obvious from the cluster that most of the buildings were belonging to long structural lives. In the sense, it is required to find the alternative means of adaptability which creates room for accommodating multi functional uses within a single structural tenure and drive towards the sustainable goals at the end.

The higher level strategies developed by 'Adaptable Futures'¹ research team, is incorporated to the framework as alternative means of deriving adaptable solutions. However, multiple terminologies are used in the industry to define the term 'adaptability'. This higher level strategies almost blended with available terminologies and limited to a seven categories. At last, the decision will be based on the economic evaluation of proposed adaptable options over new construction.

Whole Life Analysis is proposed by this framework as the technique to evaluate the economic feasibility of decisions. BSRIA (2008) defines WLA as a method of project economic evaluation in which all costs arising, and benefits accrued from installing, operating, maintaining and ultimately disposing of a project. Although this study focused to find the best economic decision on adaptable buildings based on the lowest whole life cost.

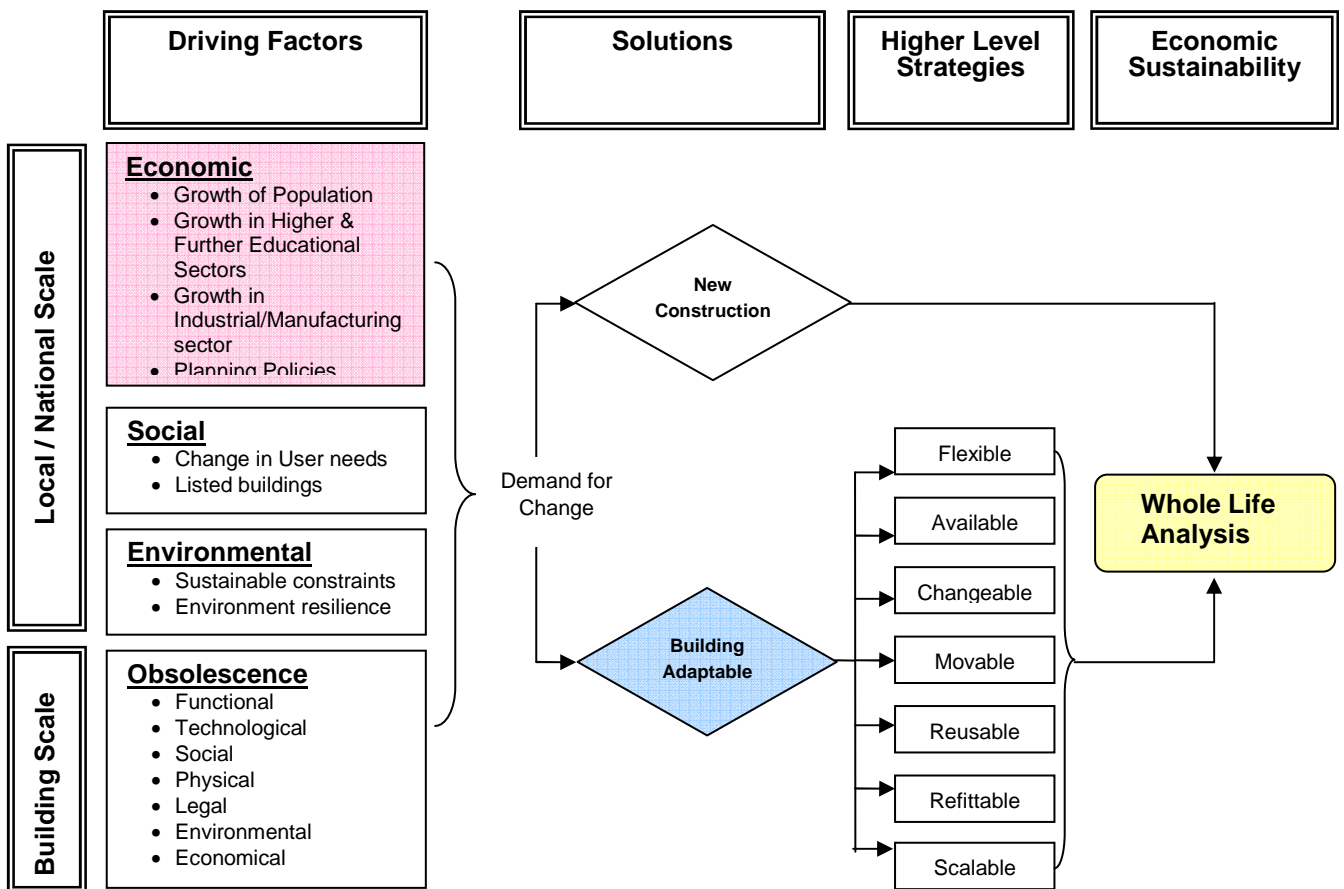


Figure 4 : Conceptual Framework

5. Conclusion

The demand for functional transformation of buildings rather their structural transformation was identified from the Morphological Analysis. Most of the original structures have converted to alternative and/or multi functions during the studied time spans. But it was found that some conversions were not fit for purpose and as a result they were demolished and new construction were undertaken. The main difficulty faced by practical changes/conversions arose because early design was not focused on future flexibility. This emphasised the importance of incorporating higher level strategies of adaptability in future new buildings which provide economically sustainable solutions for the whole country.

¹ Integrated research project, funded by the Research Council (EPSRC) through Loughborough's Innovative Manufacturing & Construction Research Centre (IMCRC), and industrial partners. www.adaptablefutures.com

It was found from the analysis that the growth in population (residents and university students) has been a considerable driving force behind the economic developments in Loughborough and the demand for functional changes in buildings. Policy makers also play a vital role in functional change. Obsolescence and its effects on the economics of the development is identified as one of the critical areas to be studied further. However, a growth in construction and its contribution to the national economy can be measured by considering buildings as a unit of analysis. The trend towards various building functions and proper balance between supply and demand is of paramount importance in a profit orientated economy. High frequency in changes of user needs and obsolescence are the most significant drivers for adaptability in the 21st century. However, buildings need to be designed to overcome those challenges in the future and they also need to become more economically viable than the renewal.

The conceptual framework developed identifies the driving factors for building space and evaluates the economic sustainability of adaptable solutions through whole life analysis. The framework needs to be tested and validated in the future.

Acknowledgement

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